2.20 DETAILED RESULTS FOR ANTENNA GAIN

The Antenna Gain Functional Element (FE) was found to be implemented as specified in Section 2.20 of ASP II. The quality of the code implementing the Antenna Gain FE is good. Internal code documentation for the FE also is good, with minor exceptions. External documentation has minor errors and is incomplete, but the quality of documentation for the included topics is good.

Table 2.20-1 summarizes the desk checking and software testing verification results for each design element in the FE. One entry is listed for each design element. The two result columns contain check marks to indicate that no discrepancies were found during verification.

TABLE 2.20-1. Verification Results Summary for Antenna Gain FE.

Design Element	Code Location	Desk Check Result	Test Case ID	Test Case Result
20-1: Antenna Gain Off-Axis Angle Dependence	ANTTRK	✔	20-1 through 20-4	✔
20-2: Lobe Gain Functions	ANTTRK CLUTG MPATH2 RDREQA RDREQT SIGJAM	✔	20-1 through 20-9	✔

2.20.1 Overview

The gain of the antenna in any given direction is the ratio of the radiated power density in that direction to the isotropic power density. The antenna gain in the direction of maximum radiation is often referred to as “the gain” of the antenna, but gain is more properly regarded as a variable function of angular direction. This function defines the radiation pattern of the antenna. Maximum gain may also be called boresight gain or beam axis gain. Gains in off-axis directions are a fraction of the beam axis (maximum) gain; off-axis gains can be represented by functions which match the antenna pattern of a system of interest.

In *RADGUNS*, the antenna pattern is defined in terms of the lobe structure of a radially symmetric beam. Beam lobes are defined in terms of local minima; the main lobe extends from the maximum at the beam axis to the first local minimum; the first sidelobe extends from the first to the second local minimum, and the second sidelobe extends from the second to the third local minimum. *RADGUNS* implements the FE primarily in Subroutine ANTTRK. This module and other subroutines that implement and utilize antenna gain calculations are briefly described in Table 2.20-2.

TABLE 2.20-2. Subroutine Descriptions.

Module	Description
AAASIM	Main routine to simulate AAA system
ANTACQ	Calculates normalized antenna gain in direction of applicable object, acquisition mode
ANTTRK	Calculates normalized antenna gain in direction of applicable object, tracking mode
CLUTG	Computes the power received from a surface clutter patch
ENGAGE	Simulates AAA system while in autotrack mode
MPATH2	Computes a multipath factor which accounts for non-direct (path) target returns
PERCUE	Searches for target with antenna cued to target position
SRCH1	Searches for target in sector search or slow circular scan mode
SRCH2	Searches for target in circular scan mode
RADAR	Controls multiple functions associated with the AAA radar
RDREQA	Computes the power received from a target during acquisition mode
RDREQT	Computes the power received from a target during tracking mode
SIGJAM	Determines the power received from each active jammer
SIGNL	Determines the target and surface clutter returns during tracking mode
Note: The modules implementing the Antenna Gain Functional Element are identified in bold letters	

2.20.2 Verification Design Elements

The Antenna Gain FE contains two design elements. A design element is an algorithm that represents a specific component of the FE design. These elements are specified in the Design Approach section of the ASP II for *RADGUNS*. The design elements for the FE are listed in Table 2.20-3.

TABLE 2.20-3. Antenna Gain Design Elements.

Module	Design Element	Description
ANTACQ ANTTRK	20-1: Antenna Gain Off-Axis Angle Dependence	Defines the angular span of the mainlobe and sidelobes
ANTACQ ANTTRK CLUTG MPATH2 RDREQA RDREQT SIGJAM	20-2: Lobe Gain Functions	Calculates the gain profile for a particular lobe

2.20.3 Desk Checking Activities and Results

The code implementing this FE was manually examined using the procedures described in Section 1.1 of this report. No code discrepancies were found during desk checking. No internal documentation problems were found. External documentation is good, except for a subroutine description error cited at the end of this Antenna Gain VR. The FE code quality is good. The internal documentation discrepancy is identified in Table 2.20-4.

TABLE 2.20-4. Code Quality and Internal Documentation Discrepancies.

Module	Code Quality	Internal Documentation
ANTTRK SIGJAM CLUTG	OK	Several variables are not defined at the beginning of the subroutine.

2.20.4 Software Test Cases and Results

Subroutine ANTTRK implements the normalized antenna gain for the subject system for both acquisition and tracking mode. Its input argument is the off-axis angle in the direction of interest. A driver was written to exercise ANTTRK within a recursive loop which increment the input angle; the resultant gain data were examined to verify correct subroutine operation. The angle normally ranges from 0 to 90 degrees for a surface-based system. For completeness, the input angles for the driver ranged from 0 to 180 degrees. Test Cases 20-1 through 20-4 are for Subroutine ANTTRK.

Test Cases 20-5 through 20-9 verify the calculation of simulated actual gain (non-normalized) in the direction of interest. User input parameter file EX2.PAR was used as delivered with the *RADGUNS* source code, except that MTI capability was disabled. Other changes are noted in the test case descriptions. The target aircraft used in these tests was the A-10A. Table 2.20-5 presents the test cases for the Antenna Gain FE.

2.20.5 Conclusions and Recommendations

2.20.5.1 Code and Algorithm Discrepancies

Verification activities revealed no discrepancies in the implementation of the Antenna Gain Functional Element in *RADGUNS* 1.9.1. Minor documentation deficiencies are described in the remainder of this section.

2.20.5.2 Code Quality and Internal Documentation

The code quality for the FE is good. Description of all code variables should be added at the beginning of FE subroutines (as well as all *RADGUNS* modules).

2.20.5.3 External Documentation

The external documentation of antenna gain in the Methodology and Design Manual (MDM, distributed with the *RADGUNS* release) has several errors, indicating that a thorough review is necessary to ensure that all future *RADGUNS* documentation is applicable to subject model release. MDM Figure 3-13 is a subroutine call hierarchy; it omits the call by subroutine CLUTG to ANTACQ before the call to ANTTRK while in perfect cueing, sector search, or circular search acquisition modes; the call hierarchy also omits the call by subroutine RDREQA to MPATH2 as well as to ANTACQ before the call to ANTTRK. In tracking mode, subroutine ENGAGE first calls RADAR, which subsequently calls SIGNL and SIGJAM; RADAR is missing from the hierarchy. The call of SIGNL to ANTTRK is incorrect; this branch should be replaced in the diagram with SIGNL calling RDREQT which callsMPATH2. Based on the module modifications to the call hierarchy, Table 3-12 should be revised to reflect the applicable module descriptions. The *RADGUNS* ASP II for antenna gain has information which should be used to correct these errors, including the incorrect flow diagram of MDM Figure 3-19.

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE.

Test Case ID	Test Case Description
20-1	OBJECTIVE: Verify correct antenna gain value assignment for the angular regions not within the mainlobe and sidelobes. PROCEDURE: 1. Copy module ANTTRK to another file; the copied file will be the subject of the driver described in the following steps. 2. Add the following statements before the first IF-THEN block of the driver: OPEN (6, File = ‘radgain1.tst’, status = ‘unknown’) WRITE (6,*)’ off-axis absolute gain dB gain’/’ angle (rad)’ FIRST(30) = .TRUE. PI = 3.14159265 3. After the data initializations of the first IF-THEN block, insert the following statement (This will generate gain data each two degrees over the entire span of off-axis angles): DO 10 I = -180,180,2 ANGLE = FLOAT(I) * PI/180. 4. After the ENDIF statement of the second IF-THEN block, insert the following statements: DBGAIN = 10. * LOG10(ANTENA) WRITE (6,9) ANGLE, ANTENA, DBGAIN 9 FORMAT(1x, f6.1, 10x, f7.1, 10x, f7.1) 10 CONTINUE CLOSE (6, Status = ‘KEEP’) 5. Execute the driver. 6. Observe the value of ALOBE3 and C7 initialized before execution of the DO loop. 7. Observe the values of DBGAIN for absolute values of angles equal to or greater than the value of ALOBE3 observed in Step 6. 8. Copy file RADGAIN1.TST to a backup file. VERIFY: The values of DBGAIN observed in Step 7 all equal the constant value of C7 observed in Step 6; this implements ASP II Equation [2.20-3]. RESULT: OK

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE. (Contd.)

Test Case ID	Test Case Description
20-2	OBJECTIVE: Verify that the mainlobe gain profile is implemented correctly. Use one-tenth degree off-axis angle increments to obtain a detailed lobe structure. PROCEDURE: 1. Repeat Steps 2 and 4 from Test 20-1. 2. After the data initializations of the first IF-THEN block, insert the following statement (This will generate gain data each one-tenth degree between negative six and six degrees): DO 10 I = -60,60 ANGLE = FLOAT(I) * PI/180. 3. Execute the driver. 4. Observe the mainlobe boundary angle ALOBE1 initialized before execution of the DO loop. 5. Observe the value of the beamwidth scale factor of C1 initialized before execution of the DO loop. 6. Observe the value of the maxima and minima of the antenna gain data generated by the driver for the mainlobe. 7. Observe the angle values corresponding to the minima of the antenna gain data generated by the driver for the mainlobe. 8. Observe the angle value corresponding to the maxima of the antenna gain data generated by the driver for the mainlobe. VERIFY: 1. The minima of the mainlobe gain observed in Step 7 occur at the value of ±ALOBE1 observed in Step 4 (within numerical accuracy limits). 2. The maximum gain value of the mainlobe observed in Step 6 equals one. 3. The maxima of the mainlobe gain observed in Step 8 occurs on boresight (defined by a zero degree offset angle). 4. The gain value at an arbitrary angle within the mainlobe observed in driver output equals independent calculation of ASP II Equation [2.20-2], using the observed value of C1 in Step 5. RESULT: OK

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE. (Contd.)

Test Case ID	Test Case Description
20-3	OBJECTIVE: Verify that the first sidelobe gain profile is implemented correctly. Use one-tenth degree off-axis angle increments to obtain a detailed lobe structure. PROCEDURE: 1. Repeat Steps 1, 2, and 3 from Test 20-2. 2. Observe the following initializations related to the first sidelobe: boundary angles ALOBE1 and ALOBE2; beamwidth scale factor C3; maximum gain C4; offset (from boresight) angle C2. 3. Continue driver execution until the first iteration at an input angle (ANGLE) greater than C2. Freeze execution, deposit a value into ANGLE equal to C2, and continue execution. 4. Observe the value of the minima and maximum of the antenna gain data generated by the driver for the first sidelobe. 5. Observe the angle values corresponding to the minima and maximum of the antenna gain data generated by the driver for the first sidelobe. VERIFY: 1. The minima of the first sidelobe gains observed in Step 4 occur at the angle values closest to ±ALOBE1 and ±ALOBE2 observed in Step 2. 2. The maximum gain value of the first sidelobe resulting from Step 3 equals the value of C4 observed in Step 2. 3. The maximum of the first sidelobe gain occurs at a corresponding offset angle equal to the value of C2 observed in Step 2. 4. The gain value at an arbitrary angle within the first sidelobe observed in the driver output equals independent calculation of ASP II Equation [2.20-2], using the observed values from Step 2. RESULT: OK
20-4	OBJECTIVE: Verify that the second sidelobe gain profile is implemented correctly. Use one-tenth degree off-axis angle increments to obtain a detailed lobe structure. PROCEDURE: 1. Repeat Steps 1, 2, and 3 from Test 20-2. 2. Observe the following initializations related to the second sidelobe: boundary angles ALOBE2 and ALOBE3; beamwidth scale factor C1; maximum gain C6; offset (from boresight) angle C5. 3. Continue driver execution until the first iteration at an input angle (ANGLE) greater than C5. Freeze execution, deposit a value into ANGLE equal to C5, and continue execution. 4. Observe the value of the minima and maximum of the antenna gain data generated by the driver for the second sidelobe. 5. Observe the angle values corresponding to the minima and maximum of the antenna gain data generated by the driver for the second sidelobe. VERIFY: 1. The minima of the second sidelobe gains observed in Step 4 occur at the angle values closest to ±ALOBE2 and ±ALOBE3 observed in Step 2. 2. The maximum gain value of the second sidelobe resulting from Step 3 equals the value of C6 observed in Step 2. 3. The maximum of the second sidelobe gain occurs at a corresponding offset angle equal to the value of C5 observed in Step 2. 4. The gain value at an arbitrary angle within the second sidelobe observed in the driver output equals independent calculation of ASP II Equation [2.20-2], using the observed values from Step 2. RESULT: OK

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE. (Contd.)

Test Case ID	Test Case Description
20-5	OBJECTIVE: Verify that the actual (non-normalized) antenna gain is calculated as the product of the maximum gain and the normalized gain in the direction of the target of interest for a radar perfect cueing acquisition mode, with no multipath contribution. PROCEDURE: 1. Choose a perfect cueing antenna search pattern by entering “PERC” at Item #4[1] and “20.” at Item #4[2] of the user input file. 2. Disable clutter/multipath capability by entering "NUME" at Item #20[1], "-101 30" at Item #20b[2], and ".00001, .00001, 30., 4000." at Item #20b[3] of the user input file. 3. Run *RADGUNS*, and follow execution from PERCUE into Subroutine RDREQA at the setting of variable TS. 4. Observe in RDREQA the value of GTARG. 5. Observe the calculation of variable FACTOR, noting the value of factor GANT. 6. Observe the value of variable ECHO, noting the use of variable FACTOR in the algebraic operation performed. 7. Follow execution into Subroutine MPATH2 at the setting of variable FMPATH in RDREQA. 8. Observe in MPATH2 the execution path to variable FMPATH (same name used in both modules). 9. Observe the calculation of variable RDREQA, noting the algebraic operation performed on variables ECHO and FMPATH. VERIFY: 1. The value of GANT observed in Step 5 equals that in Subroutine RDRDAT. 2. The execution path to FMPATH in Step 8 bypasses the first branch (multipath calculation) and assigns the gain of the target signal without multipath contribution. 2. Variable FACTOR from Step 6 is a multiplicative factor. 3. Variables FMPATH and ECHO are multiplied in Step 9; this establishes that the maximum antenna gain (GANT used in calculating ECHO) and the normalized gain in the direction of the target of interest (GTARG used in calculating FMPATH) are multiplied, which implements calculation of the non-normalized antenna gain in the target direction described by ASP II Equation [2.20-4]. RESULT: OK

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE. (Contd.)

Test Case ID	Test Case Description
20-6	OBJECTIVE: Verify that the actual (non-normalized) antenna gain is calculated as the product of the maximum gain and the normalized gain in the direction of the target of interest for an acquisition radar circular search pattern, and with clutter contribution. PROCEDURE: 1. Choose a circular antenna search by entering “CIRC” at Item #4[1] and “60.” at Item #4[2] of the user input file. 2. Choose the numerical clutter/multipath algorithm by entering “NUME” at Item #20[1], “2. 30." at Item #20b[2], and “.3 .4 30. 4000." at Item #20b[3] of the user input file. 3. Run *RADGUNS*, and follow execution from SRCH1 into Subroutine CLUTG at the setting of variable CL. 4. Observe in CLUTG the calculation of variable FACTOR, noting the algebraic operation on variable $GANT^2$. 5. At the setting of variable ANTENA, follow execution into module ANTACQ, and observe the call to ANTTRK, noting the returned value; also note the value of ANTENA. 6. Observe the calculation of variable CLUTG noting the algebraic operation performed on variables FACTOR and $ANTENA^2$. VERIFY: 1. Variable FACTOR from Step 4 is set using $GANT^2$ a multiplicative factor. 2. ANTENA is set to the calculated value of ANTTRK in Step 5. 3. Variables FACTOR and $ANTENA^2$ are multiplied in Step 6; this establishes that the maximum antenna gain (GANT used in calculating FACTOR) and the normalized gain in the direction of the target of interest (GTARG used in calculating FMPATH) are multiplied (both are squared to apply to power gain instead of signal gain), which implements calculation of the non-normalized antenna gain in the target direction described by ASP II Equation [2.20-4]. RESULT: OK

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE. (Contd.)

Test Case ID	Test Case Description
20-7	OBJECTIVE: Verify that the actual (non-normalized) antenna gain is calculated as the product of the maximum gain and the normalized gain in the direction of the target of interest for an acquisition radar sector search pattern, and with multipath contribution. PROCEDURE: 1. Choose a circular antenna search by entering “SECT” at Item #4[1] and “0. 6. 60." at Item #4[2] of the user input file. 2. Choose the numerical clutter/multipath algorithm by entering "NUME" at Item #20[1], "2., 30." at Item #20b[2], and ".3, .4, 30., 4000." at Item #20b[3] of the user input file. 3. Run *RADGUNS*, observe the initialized value of GANT in subroutine RDRDAT, and follow execution from SRCH1 into Subroutine RDREQA at the setting of variable TS. 4. Observe in RDREQA the value of GTARG. 5. Observe the calculation of variable FACTOR, noting the value of factor GANT. 6. Observe the value of variable ECHO, noting the use of variable FACTOR in the algebraic operation performed. 7. Follow execution into Subroutine MPATH2 at the setting of variable FMPATH in RDREQA. 8. Observe in MPATH2 the calculation of FMPATH, noting the use of variables GMPATH and GTARG in the algebraic operation performed. 9. Observe the calculation of variable RDREQA, noting the algebraic operation performed on variables ECHO and FMPATH. VERIFY: 1. The value of GANT observed in Step 5 equals that of the initialized value of GANT in Subroutine RDRDAT. 2. Variable FACTOR from Step 6 and GTARG from Step 8 each are a multiplicative factor. 3. Variables FMPATH and ECHO are multiplied in Step 9; this establishes that the maximum antenna gain (GANT used in calculating ECHO) and the normalized gain in the direction of the target of interest (GTARG and GMPATH used in calculating FMPATH) are multiplied, which implements calculation of the non-normalized antenna gain in the target direction described by ASP II Equation [2.20-4]. RESULT: OK

TABLE 2.20-5. Software Test Cases for the Antenna Gain FE. (Contd.)

Test Case ID	**Test Case Description**
20-8	OBJECTIVE: Verify that the actual (non-normalized) antenna gain is calculated as the product of the maximum gain and the normalized gain in the direction of the target of interest during tracking with no jammers present. PROCEDURE: 1. Choose a sector antenna search by entering “SECT” at Item #4[1] and “0 6 60" at Item #4[2] of the user input file. 2. Disable clutter/multipath capability by entering "NUME" at Item #20[1], "-101 30" at Item #20b[2], and ".00001, .00001, 30., 4000." at Item #20b[3] of the user input file. 3. Run *RADGUNS*, and observe the use of variable GANT in the algebraic operation of the initialization procedure of common variable FACTOR in Subroutine RDRDAT. 4. Observe execution from Subroutine ENGAGE to Subroutine RADAR to Subroutine SIGNL at the setting of GTARG and GMPATH (in SIGNL). 5. At the setting of TS in SIGNL, follow execution into Subroutine RDREQT. 6. Observe the value of variable ECHO, noting the use of variable FACTOR in the algebraic operation performed. 7. Observe the calculation of variable RDREQT within function RDREQT, noting the algebraic operation performed on variables ECHO and FMPATH. VERIFY: 1. The value of GANT observed in Step 5 equals that in Subroutine RDRDAT. 2. Variable FACTOR from Step 3 is calculated using GANT as a multiplicative factor. 3. The calls to ANTTRK in the setting of variables GTARG and GMPATH in Step 4 occur without error. 4. Variable FACTOR from Step 6 is a multiplicative factor. 5. Variables ECHO and FMPATH are multiplied in Step 7; this establishes that the maximum antenna gain (GANT used in calculating ECHO) and the normalized gain in the direction of the target of interest (GTARG and GMPATH used in calculating FMPATH) are multiplied, which implements calculation of the non-normalized antenna gain in the target direction described by ASP II Equation [2.20-4]. RESULT: OK
20-9	OBJECTIVE: Verify that the actual (non-normalized) antenna gain is calculated as the product of the maximum gain and the normalized gain in the direction of a jammer. PROCEDURE: 1. Choose a circular antenna search by entering “CIRC” at Item #4[1] and “60.” at Item #4[2] of the user input file. 2. Choose the numerical clutter/multipath algorithm by entering "NUME" at Item #20[1], "2., 30." at Item #20b[2], and ".3, .4, 30., 4000." at Item #20b[3] of the user input file. 3. Observe execution from Subroutine ENGAGE to Subroutine RADAR to Subroutine SIGJAM. 4. Observe in SIGJAM the calculation of variable JAMFAC, noting the algebraic operation performed on variables GTARG and GANT. VERIFY: Variables GTARG and GANT are multiplied in Step 4; this establishes that the maximum antenna gain (GANT) and the normalized gain in the direction of the jammer (GTARG) are multiplied, which implements calculation of the non-normalized antenna gain in the target direction described by ASP II Equation [2.20-4]. RESULT: OK

An explanation should be added to antenna gain methodology descriptions to indicate that gain in the direction of the target of interest is simply the product of the normalized antenna gain (in the target direction) and the maximum radar gain.

Subroutine descriptions for modules (for several systems) implementing antenna gain are included in Appendix C of the MDM; definitions of all global variables should be added to the subroutine description. The calling sequences for RDREQA and RDREQT as documented in Appendix C do not accurately reflect the implemented code; RDREQA has nine implemented arguments, while the documentation cites only six. Also, the first two arguments of RDREQT are not the same as those documented in Appendix C. These discrepancies should be corrected.

DRAFT